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TITLE:	FLUX-CORED ARC WELDING – A BRIEF NOTE ON THE PROCESS & PARAMETERS

CONTENTS:

1.0 Introduction

Flux Cored Arc Welding (FCAW) is an arc welding process wherein the heat for welding is produced by an electric arc between a continuously fed flux-cored tubular electrode (wire) and the work piece (Figure 1). Shielding is provided either by the flux contained within (self-shielded FCAW) or may be supplemented with an external shielding gas (gas-shielded FCAW). The gas provides a protection of the arc and the weld pool from the contamination of nitrogen and oxygen in the atmosphere. The core ingredients in the conventional gas-shielded FCAW process act as slag formers, deoxidizers, arc-stabilizers and alloying additions (Table-1). The FCAW process encompasses the benefit of continuous welding like solid wire & that of alloying & positional welding features through flux like manual metal arc welding. A schematic sketch of the manufacturing of this wire is shown in figure-2.

Table 1: The function of some commonly used core ingredients in FCAW process

Core ingredients	Gas former	De-oxidizer	De-nitrifier	Slag former	Viscosity control	Arc stabilizer	Alloying
Rutile				√	√		
Fluorspar				√	√		
Lime	√			√		√	
Feldspar				√		√	
Synthetic frits				√	√	√	
Manganese		√					√
Silicon		√					√
Titanium		√	√				
Aluminium		√	√				
Cr, Ni, Mo, etc							√

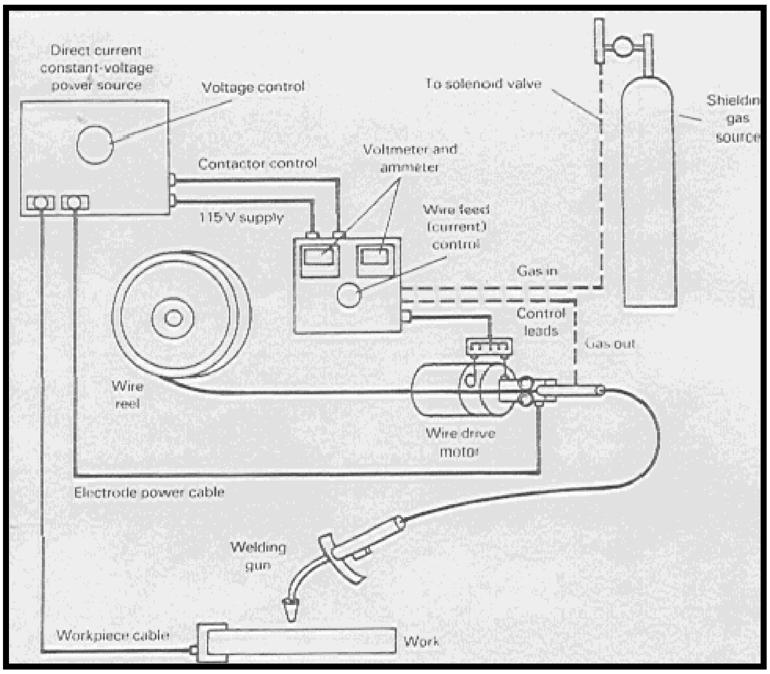

Figure-1: Schematic sketch of the flux-cored arc welding process

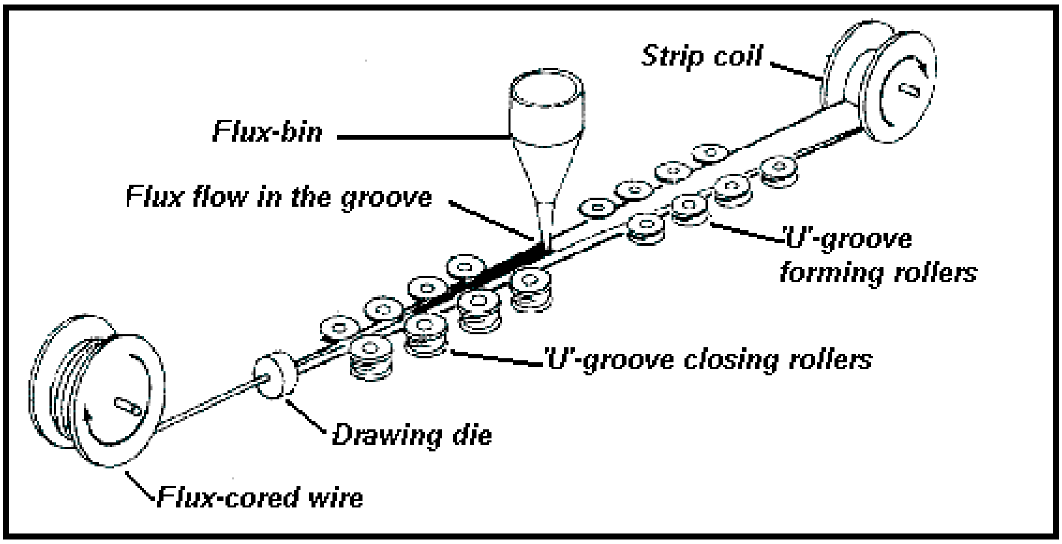

Figure-2: Schematic sketch of the manufacturing line

2.0 Classification system as per AWS standard (SFA 5.20)

E X X T – X M J H Z

(a) (b) (c) (d) (e) (f) (g) (h)

(a) Indicates as an electrode (E).

(b) Indicates in 10 ksi (kilo-pound per square inch) increments, the minimum tensile strength of the weld metal produced by the electrode.

(c) Indicates the welding position of the designed electrode. (0)- flat and horizontal position, and (1)- for all positions.

(d) Indicates a flux-cored electrode.

(e) Indicates the usability and performance of the electrode ‘G’ indicates that the external shielding, polarity and impact properties are not specified. The ‘S’ indicates that the electrode is suitable for single pass alone (Table-2).

(f) M indicates that the electrode is classified using 75-80% argon/balance CO_2 shielding gas. In other cases, either carbon dioxide acts as shielding gas or the electrode is self-shielded.

(g) ‘J’ indicates the weld metal meets the impact toughness of 27 J at –40°C.

(h) Indicates the optional requirements of diffusible hydrogen in the deposited weld metal. H4, H8, H16 represents average maximum allowable diffusible hydrogen to be of 4, 8 and 16 ml/100 gm of weld metal respectively.

Table 2: Usability type designator for flux-cored electrodes

Type	Shielding	Single/ Multi-pass	Transfer mode	Impact toughness, J	Polarity	Special characteristics
T-1	Gas	Multi-pass	Spray-like	27 at –18°C	DCEP	Low spatter, full slag coverage
T-2	Gas	Single	Spray-like	Not required	DCEP	Low spatter, full slag coverage, high deoxidizers
T-3	Self	Single	Spray-like	Not required	DCEP	High speed
T-4	Self	Multi-pass	Globular	Not required	DCEP	High deposition, low penetration, crack resistant
T-5	Gas	Multi-pass	Globular	27 at –30°C	DCEP	Improved toughness, crack resistant, thin slag
T-6	Self	Multi-pass	Spray-like	27 at –30°C	DCEP	Improved toughness, deep penetration
T-7	Self	Multi-pass	Globular	Not required	DCEN	Crack resistant, good slag removal
T-8	Self	Multi-pass	Globular	27 at –30°C	DCEN	Improved toughness, crack resistant
T-9	Gas	Multi-pass	Globular to Spray	27 at –30°C	DCEP	Improved toughness, crack resistant
T-10	Self	Single	Globular	Not required	DCEN	High speed
T-11	Self	Multi-pass	Spray-like	Not required	DCEN	General purpose
T-G	(a)	Multi-pass	(a)	Not required	(a)	(a)
T-GS	(a)	Single	(a)	Not required	(a)	(a)

(a) The corresponding parameters are not mentioned.

3.0 Selection of process parameters based on weld quality & performances

A strict control over the welding parameters is mandatory for achieving quality and high-productive joint in both GMAW and FCAW processes. The characteristic feature of each variable is summarized below.

3.1 Welding Current – The welding current is proportional to electrode feed rate provided the composition, diameter and extension of electrode remains unaltered. Electrode is melted using a constant voltage type power source with a preset voltage (arc length). If the other process variables and diameter of the electrode are not varied, major changes in the performance are observed with variation of welding current.

1) Electrode deposition rate increases with increase in welding current.
2) Increase in current increases weld bead penetration.
3) A poor appearance and convexity of weld bead appears with excessive current.
4) Insufficient current produces large droplet transfer and causes excessive spatter.
5) Insufficient current causes nitrogen pick up and also thereby porosity in the weld metal with self-shielded FCAW due to resultant lower arc force.

3.2 Arc Voltage – The arc voltage that is shown in the meter of the power supply is the sum of total voltage-drop in the welding circuit. This includes; the drop through the welding cable, the electrode extension, the arc, the work piece and the ground cable. Therefore, all other circuit elements are to be constant to obtain proportionate meter reading and arc voltage.

1) Too high an arc voltage (too long an arc) will result in excessive spatter and wide, irregularly shaped weld beads. A long arc gap during welding promotes more pick up of nitrogen from atmosphere. For mild steel it will result to form porosities and in stainless steels a lowering of ferrite content which in turn may cause for solidification cracking.

2) Too low an arc voltage (too short an arc) will result in narrow and convex beads with excessive spatter and poor penetration.

3.3 Electrode Extension – The length of the wire extended beyond the tip of the nozzle to the arc pool is referred as the electrode extension. It affects the shielding conditions, arc energy, electrode deposition rate and weld penetration. If the electrode manufacturer does not specify it, an extension of 19 to 38 mm for gas shielded electrodes and approximately 19 to 95 mm for self-shielded electrodes can be applicable depending on the application.

1) Longer arc extension results to form an unstable arc with excessive spatter. In gas shielded metal arc welding it results poor gas coverage of the weld pool resulting porosities and related defects.
2) Too short an arc length is also undesirable due to excessive spatter.

3.4 Travel Speed – Heat input in the weld is inversely proportional to the arc travel speed. So, both too high and too low a travel speed is equally detrimental to the weld metal quality. It also results to form a poor bead appearance with a possibility of entrapped slag for higher arc travel speeds.

3.5 Shielding Gas Flow – The gas flow rate is an important factor to obtain a good quality weld joint. A poor shielding will result for a low gas flow rate, on the other hand too high a flow rate will create turbulence in the molten weld puddle causing porosities, slag entrapment and poor weld bead appearance. The correct gas flow rate should be selected on type and diameter of the gun nozzle, nozzle to work distance and rate of air flow in the vicinity of the welding operation.

3.6 Electrode Angle – The angle of the electrode determines the direction of arc force applied to the weld pool. Proper drag angle (between the weld axis and vertical plane) is maintained to achieve the desired weld penetration for thin or thick sections. For horizontal and flat positions, drag angle of 20° to 45° is usually maintained in self-shielded arc welding for thick and thin sections respectively. The angle is decreased for thicker sections to increase penetration. Not the penetration alone, the arc force is responsible to maintain the shape of the desired weld bead shape too. It prevents the slag running ahead of the weld pool and entrapment in the weld metal. For vertical-up welding, the drag angle should be 5° to 10°.

Usually a lower drag angle (2° to 15°) is maintained for gas-shielded arc welding. The effectiveness of the shielding gas is lost with higher welding angle and generally it does not exceed 25°. For fillet welds in horizontal position, the liquid metal in the weld pool tends to flow in the welding direction as well as right angle to it. A work angle (between the axis and the vertical member) of 45° to 50° is thus used to counteract the flow in the latter direction.

4.0 COMMON FLUX CORED ARC WELDING DEFECTS:

The process variables, materials or welding procedures can affect the weld quality. Some of the commonly observed defects in FCA welding and their possible remedies are tabulated below.

	Possible Causes	***Corrective Actions***
	Weld metal cracks	
1.	Too high a weld depth-to-width ratio.	• Increase the arc voltage or decrease the welding current.
2.	Too small a weld bead.	• Decrease the travel speed.
3.	Rapid cooling of the crater at the end of the weld.	• Fill craters adequately. • Use a back step welding technique at the end to complete the weld bead.
	Inclusions	
1.	Use of multiple pass, short circuiting type welding (slag).	• Clean the previous bead before making subsequent passes.
2.	High travel speeds (film type inclusions).	• Reduce the travel speed. • Increase the arc voltage.
	Porosity	
1.	Inadequate shielding of arc and weld pool.	• Increase the shielding gas flow. • Remove the spatter from the interior part of the nozzle. • Eliminate drafts (from fans, open doors etc.)

		blowing into the welding arc. • Reduce the travel speed. • Reduce the arc gap. • Hold the gun till the molten crater solidifies.

Possible Causes	***Corrective Actions***

2.	Electrode contamination.	• Use clean and dry electrodes. • Eliminate contamination of electrode wire with any lubricant.
3.	Work-piece contamination.	• Remove oil, grease, rust, paints and dusts from the work surface prior to welding.
4.	Arc voltage too high.	• Reduce the operating voltage.
5.	Excess nozzle-to-work distance.	• Reduce electrode extension.

Incomplete fusion

1.	Work-piece surface not clean.	• Clean all groove surfaces and weld zones.
2.	Insufficient heat input.	• Increase the electrode feed rate and the arc voltage. • Decrease the travel speed.
3.	Too large a weld puddle.	• Reduce arc weaving.
4.	Improper welding technique.	• Direct the electrode at the leading edge of the weld pool. • During weaving hold momentarily on the groove face.
5.	Improper joint design.	• Select proper groove design. • Maintain a proper groove angle to provide an easy access to electrode extension.

Lack of penetration

1.	Improper joint preparation.	• Provide/Increase root openings in butt-joint. • Decrease the height of root face. • Adequate access to maintain proper nozzle-to-work distance.
2.	Improper welding technique.	• Maintain the arc on the leading edge of the weld pool. • Select proper travel angle to achieve maximum penetration.

3.	Inadequate heat input.	• Increase electrode feed rate. • Maintain proper nozzle-to-work distance.

Excessive melt through

1.	Excessive heat input.	• Reduce the electrode feed rate & voltage. • Increase the travel speed.
2.	Improper joint preparation.	• Reduce excessive root opening. • Increase the height of the root face.

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